Short Communication: Use of a Diagnostic Software to Predict Bone Density and Implant Stability in Preoperative CTs

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ABSTRACT

Background: Computerized tomographs (CTs) are commonly used for presurgical planning of dental implant placement. It is possible that implant stability can be predicted based on quantitative measurements of bone density at planned implants sites with the use of diagnostic software.

Purpose: The aim was to evaluate if there is a correlation between bone density measurements in specific implant positions in preoperative CTs and insertion torque (IT) and implant stability measurements when placing the implants.

Materials and Methods: The study comprised of four patients in whom presurgical CTs had been used to plan implant treatment. A total of 26 implants (Neoss, Harrogate, UK) were placed in the totally edentulous maxilla ($n = 3$) or mandible ($n = 1$). IT was measured during implant insertion and the torque/time curves examined for mean IT (newton-centimeters) over the total curve. The stability of implants was measured with resonance frequency analysis. The positions of the implants were extracted from a postoperative CT to the preoperative one. Bone density was measured with a dedicated software (3Diagnosys™ 3.0, 3Diemme, Cantù, Italy) in virtual hollow probes, indicating the bone volume within 1 mm from each implant surface. The Spearman Rank correlation test was used to find possible correlations.

Results: Statistically significant correlations were found between mean bone density, mean IT, and implant stability measurements.

Conclusions: This pilot study showed a correlation between bone density, as measured in Hounsfield units in preoperative CTs, and IT and implant stability measurements at the surgical placement of the implants. The findings support the idea that integration of bone density measurements in implant probes in preoperative CTs using treatment-planning software may be a useful feature to predict implant stability and to avoid failures.

KEY WORDS: dental implants, Hounsfield units, insertion torque measurements, radiography

INTRODUCTION

Clinical studies have shown dental implants with low primary stability to be less successful than more stable ones.[1] Thus, it is important to be able to identify implant sites at risk for failure preferably during presurgical planning. Insertion torque (IT) and resonance frequency analysis (RFA) are examples or techniques, which have been shown useful to evaluate primary implant stability. Peak IT describes the torque in newton-centimeters (Ncm) when an abrupt stop of an implant is observed during insertion with motor or hand wrench.[2] Continuous registration of IT (cutting resistance) during implant insertion, on the other hand, reveals density information from the whole bone-implant interface based on consumed energy during cutting/insertion.[3,4] The resultant torque is a combination of the resistance from the cutting edges of the apical configuration and friction from the body of the implant. A good correlation has been shown between IT measurement and bone density profiles as measured in

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microradiographs of bone specimens after implant insertion.[4] RFA measures implant stability as a function of stiffness. A transducer is attached to an implant and excited over a range of frequencies to find the resonance frequency,[5] which is transformed into an implant stability quotient (ISQ) unit. Both IT and RFA measurements have been shown to correlate with bone density at the site and to each other.[6–8] Thus, both techniques yield relevant information about an implant site and stability but can only be applied during surgery. Numerous computer software for three-dimensional reconstruction of the jaws based on computerized tomograms (CTs) have been introduced on the market.[9] Implant positions and angulations can be virtually planned and the information transferred to a surgical guide. The use of CT also gives the possibility of extracting quantitative bone density information in Hounsfield units (HUs).[10] Studies in vivo[7] and in vitro[8,11] have shown a correlation between HU measurements and both IT and RFA measurements. This suggests that preoperative bone density measurements may be used to predict implant stability if integrated in treatment-planning software.

The aim of this study was to evaluate if there is a correlation between bone density measurements, using a virtual implant-probe in preoperative CTs and IT and RFA measurements when placing the implants.

MATERIALS AND METHODS

The study comprised of four patients (two female, two male) with a mean age of 67.3 years (range 64–72) and in need of prosthetic rehabilitation with implants due to total edentulism in the maxilla ($n = 3$) and mandible ($n = 1$). The patients gave written informed consent. The presurgical and postsurgical examination CTs were taken with a Toshiba CT (Toshiba Medical Systems Srl, Rome, Italy) ($n = 2$) or a GE Medical Systems CT (GE Healthcare Technologies, Milano, Italy) ($n = 2$). Both instruments were regularly calibrated with regard to HUs.

A total of 26 implants (Neoss Ltd., Harrogate, UK) were placed with local anesthesia and premedication with antibiotics as described elsewhere[12] (Table 1). Bone quantity and quality at the implant sites were assessed according to the Lekholm and Zarb index (Table 2).[13]

IT was measured during implant insertion with an Elcomed™ SA200C drilling unit (W & H, Bürmoos, Austria) at 20 rpm and 8 Hz to a maximum torque of 50 Ncm. The data were imported and analyzed in specially designed software (Impdat™, Kea Software GmbH, Poecking, Germany). The torque/time curves were examined for mean IT (Ncm) over the total curve.

Implant stability was measured with RFA in ISQ units with a Smartpeg™ and Mentor™ instrument (Osstell AB, Gothenburg, Sweden).

A second CT was taken after placement of the implants. A special software (Geomagic Studio 11, Research Triangle Park, NC, USA) was used to superimpose the positions of the implants as extracted from the postoperative CT to the preoperative one (Figure 1A). With another software (3Diagnosys™ 3.0, 3Diemme, Cantu, Italy), a hollow cylindrical probe, mimicking the implant length and the bone within 1 mm from the implant threads, was created (Figure 1, B–D). The probes were placed in the presurgical CT in exact positions as the implants (Figure 1, C–D). Bone density data were exported for every voxel inside the probe and expressed as the mean HU.

The Spearman's rank correlation test was used to find possible correlations between mean bone density in HUs, mean IT in Ncm, and implant stability in ISQ values.

TABLE 1 Implant Lengths and Diameters Used in the Study

	Implant Lengths (mm)		
Implant Diameter (mm)	11	13	15
3.5	–	1	2
4.0	2	12	6
4.5	2	–	–
5.5	–	1	–

TABLE 2 Bone Quality and Density According to Lekholm and Zarb Index

	Bone Quality			
Bone Quantity	1	2	3	4
A	–	–	–	–
B	1	16	3	3
C	–	1	2	–
D	–	–	–	–
E	–	–	–	–

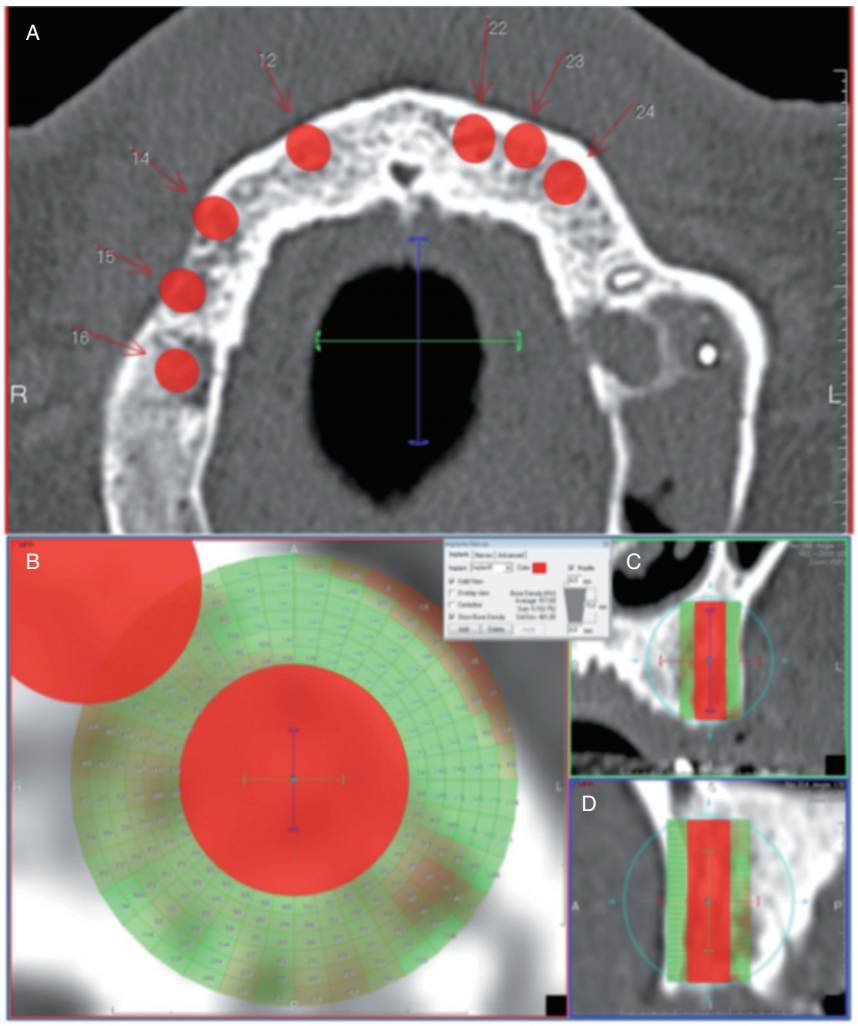

Figure 1 *A*, The positions of the implants, extracted from the postoperative computerized tomogram (CT), have been superimposed on the presurgical CT. *B–D*, A hollow probe indicating the body of the implant (red) and area within 1 mm from the implant threads (green) has been created and placed in implant positions. Bone density data were then exported based on all voxels inside the green area and expressed as the mean Hounsfield unit of the probe.

RESULTS AND DISCUSSION

The measurements showed a mean bone density of 657.6 ± 240.7 HU, a mean IT of 12.2 ± 6.6 Ncm, and a mean implant stability of 75.0 ± 5.9 ISQ for all 26 implants (Table 3).

The correlation analyses revealed a significant relationship between mean bone density inside the implant probes and IT (Table 4) (Figure 2). This is in line with previous in vitro work,[11] and shows that continuous IT measurements give relevant information about an implant site also in vivo. Previous studies used well-defined screw-taps or parallel-walled implants for measurements,[3,4,11] where the true cutting resistance created more and friction less of the resistance to torque. The presently used implant was slightly tapered, which means that the whole length of the implant counteracted with the bone and that friction presumably represented a higher degree of resistance than if a parallel-walled implant had been used. It can be speculated that a tapered implant may mask the true cutting resistance and density profile during insertion. On the contrary, the present study showed that the IT data from placement of a tapered implant correlated well with bone density measurements in CTs. Moreover, an in vitro study in a cadaver bone using the same implant also reported a correlation between peak IT and HU measurements.[8]

A statistically significant correlation was found between mean bone density and implant stability measurements in ISQ units (Table 4) (Figure 3), which

TABLE 3 Measurement Results of Mean Bone Density (HUs) in Preoperative CTs and of Mean IT and Implant Stability at Implant Placement

Parameter	No.	Mean	Std Dev.	Range
Mean bone density (HU)	26	657.6	240.7	139.9–1085.5
Mean IT (Ncm)	26	12.2	6.6	3.1–28.3
Implant stability (ISQ)	26	75.0	5.9	56–85

CT = computerized tomograms; HU = Hounsfield unit; ISQ = implant stability quotient; IT = insertion torque.

corroborates with the results from other studies.[7,8] Previous studies have shown that the properties of the marginal bone determine implant stability.[6,14] For instance, implant length was not shown to have a positive influence on RFA.[14] It is possible that the mean HU value of the present study was greatly influenced by high density of the marginal cortical bone. This ought to be tested in future studies where bone density in the marginal and medullar parts should be separated. Nevertheless, a strong correlation was found between mean bone density and ISQ value in the present study.

The statistical analyses showed a significant correlation between mean IT and implant stability in ISQ units (Table 4) (Figure 4), which also has been reported in other in vitro[8] and in vivo[7] studies. Previous studies using parallel-walled implants have demonstrated a strong relation between IT of the first 1/3 of the implant site and ISQ value,[6] which is in analogy with the HU/ISQ relationship as discussed above. A correlation was found between mean IT over the total curve and implant stability in the present study. It can be speculated that a tapered implant design is more sensitive in reflecting bone density than a parallel-walled implant, since, as discussed above, the total implant length contributes to the IT measurements in the form of cutting torque and friction.

TABLE 4 Results from Statistical Analyses Using the Spearman's Rank Correlation Test

Tested Parameters	Correlation Coefficient	*p* Value
Mean bone density – Mean IT	0.73	0.0002
Mean bone density – Implant stability	0.54	0.004
Mean IT – Implant stability	0.66	0.0009

IT = insertion torque.

The findings from the present study are in line with those from other clinical and in vitro studies using both parallel-walled and tapered implant designs. Turkyilmaz and McGlumphy studied bone density and implant stability for 300 implants where 20 failed during a 3-year period.[15] They reported significantly lower HU, peak IT, and RFA values for the failed implants when compared to the successful ones.

The findings from the present study support the idea that integration of quantitative bone density

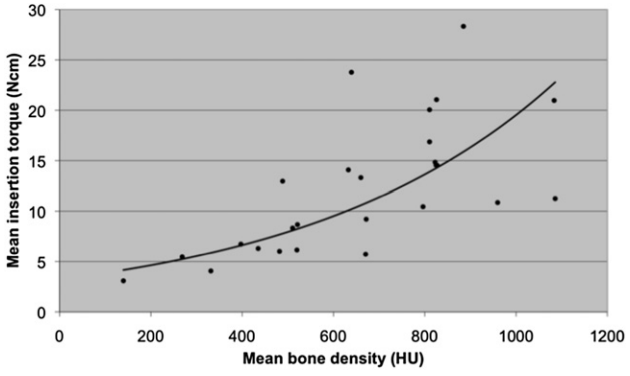

Figure 2 Correlation plot of mean bone density (Hounsfield unit [HU]) and mean insertion torque (newton-centimeters) (Rho = 0.73, $p = 0.0002$).

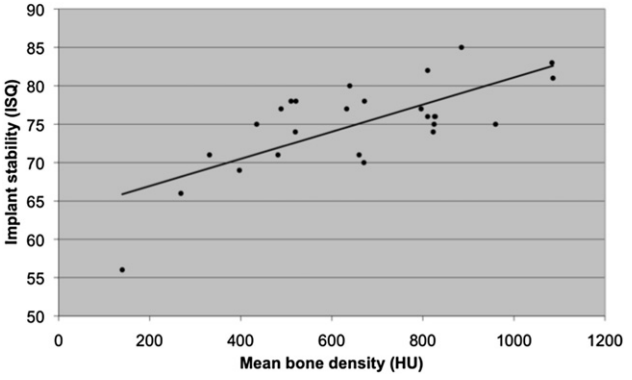

Figure 3 Correlation plot of mean bone density (Hounsfield unit [HU]) and implant stability (implant stability quotient [ISQ]) (Rho = 0.57, $p = 0.004$).

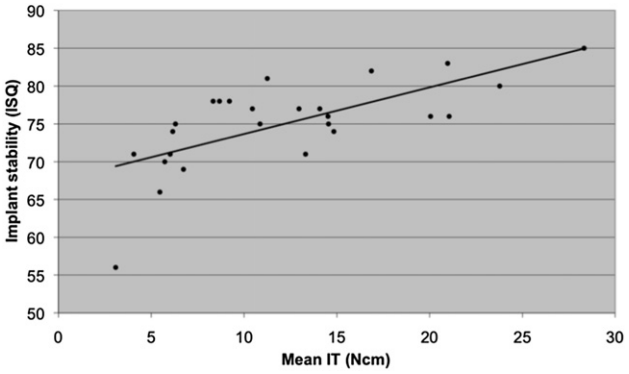

Figure 4 Correlation plot of mean insertion torque (IT) and implant stability (implant stability quotient [ISQ]) (Rho = 0.66, $p = 0.0009$).

measurements in treatment-planning software may be a useful feature to predict implant stability and to avoid failures. However, prospective studies are needed to confirm this hypothesis.

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